Economics of a US Integrated Ocean Observing System

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1. Introduction

The United States has long made significant investments in ocean research, monitoring and forecasting. Nonetheless, ocean phenomena remain under observed compared to observations of atmospheric conditions, and there has been little high-level coordination of ocean data collection. Observations from ships and buoys are sparse compared to onshore environmental monitoring, and satellite data are pervasive but not comprehensive. Large expanses of the oceans remain unobserved, by ship or satellite, for substantial periods of time.

Development of an Integrated Ocean Observing System (IOOS) is a major shift in the approach to ocean observation. By systematically collecting data and integrating hundreds of thousands of measurements from the world's oceans in conjunction with mathematical models, a more sophisticated understanding of ocean-related systems becomes possible. This will improve short-term weather forecasts, seasonal weather forecasts, marine forecasts, environmental assessments, and opportunities for basic research, thereby producing benefits for people and businesses throughout the US economy and internationally.

The evidence from benefit studies to date suggests that, nationally, a major benefit of ocean observations is to improve weather and climate forecasts that are used throughout the economy and produce hundreds of millions of dollars in annual benefits to the United States and to the world economy. Benefits beyond those counted for weather and climate forecasts have been demonstrated at the regional level through preliminary studies in the Gulf of Maine.

Additional research is needed to obtain reasonable estimates of the benefits accruing to a number of sectors from IOOS data and products will differ from those currently available, their incremental costs, how the information is used in decision making, and how that information improves outcomes in economic activities. Ranking IOOS products according to their net benefit is one useful tool to help prioritize investments in improved ocean observing infrastructure.

2. Background: Rationale for Federal Support of IOOS

IOOS produces economic value when information derived from IOOS data is made available in a timely manner to those who can use it in economic decisions. This sort of information has some of the characteristics of what economists refer to as a "public good." In particular, once it is produced, information is now almost costless to distribute (e.g., via the Internet), and the total benefit derived from the information is greatest when it is made available to anyone who can make use of it. In some instances – for example, severe marine weather warnings – it is also difficult (or ethically problematic) to exclude potentially affected parties from obtaining the information, whether they have paid for it or not. Finally, some information produced by IOOS may improve long-term public policy decisions that affect everyone in the country (or the world).

These public good characteristics suggest that private investment is likely to produce less information about the oceans than is socially optimal. The direct incentive for any individual or business to invest in generating the information is limited to the value they themselves receive. Many potential beneficiaries may not invest at all, preferring to take advantage of information provided by others. Moreover, the transaction costs involved in negotiating private cooperative agreements to realize the full benefits of IOOS are likely to be formidable. All these problems are largely resolved by public investment in IOOS and wide dissemination of (some) resulting information products.

The public good characteristics of IOOS thus argue for Federal support in order to achieve the full benefits of this system. However, the fact that there is a compelling case for public involvement does not mean that any investment should be made. The investment should be made only if the benefits of the system can be reasonably expected to exceed its costs. This can only be determined if a reasonable estimate of costs can be made, and if both the uses of the data, and the value of that use, can be reasonably estimated.

3. Benefits and Costs

<u>Benefits</u>. Ocean observation has economic benefits because the data are used to derive products, such as forecasts, that are used by decision makers to make choices that affect economic well-being. To estimate the benefits that may accrue from an investment in IOOS, it is necessary to compare the outcome of these decisions under two scenarios: the baseline situation (currently available information and products) and the hypothetical future situation with IOOS data and products. The new information products enabled by IOOS data will alter decisions made in industry, recreation, and public administration, changing the economic outcome from these activities, and thereby affecting economic well-being. The difference in outcome under the two scenarios is the benefit derived from IOOS.

The most accurate measure of this benefit is the marginal increase in consumer and producer surplus. Consumer surplus is the difference between what consumers are willing to pay and what they actually pay. Producer surplus is the difference between the price received for a good or service sold and the costs of producing that good or service. Because this surplus is often difficult to estimate, we also use other measures of benefit, such as the change in value added, or reduction in cost to achieve the same level of output, although these are less precise estimates of true social surplus. Usually, these measures are estimated as annual values at the level of a firm or other economic unit, and then aggregated over geographic regions and industries to estimate total annual benefits.

Costs. Benefits represent only one side of the economics of IOOS. To estimate net benefits, or rates of return, it is necessary to have information on costs as well. There are two categories of costs: the funding for IOOS data collection, processing, and archiving; and the costs of generating the products from IOOS data that decision makers ultimately use. The second component includes activities carried out by both public and private sector organizations. As with benefits, we are interested in the marginal increase in annual costs, or the difference between costs under the current scenario and expected costs under IOOS.

Current federal support for ocean research is about $600 million a year, some portion of which supports activities that may become part of IOOS. Cost estimates for IOOS specifically have been difficult to generate because the system itself is not yet fully defined. Rough estimates of additional costs to implement a coherent US ocean observing system have been on the order of $100 million annually. According to preparatory documents for the 1992 Rio Conference, the project annual operating cost of a fully implemented Global Ocean Observing System, of which IOOS will be a part, was thought to be approximately $2 billion.

4. An Economic Framework for Planning IOOS

At a simple level, IOOS will consist of a network of sensors and platforms that feed observations into a data management system. The data system in turn feeds a variety of models that generate forecasts, nowcasts, and other decision support tools, and also supplies data sets for scientific research. An economic approach to planning investment in IOOS begins at the "product and user" end of the system. It assigns to each product (for example, an ENSO forecast) a measure of benefit (marginal increase in social surplus) and cost (marginal cost of collecting and processing the data). Subtracting cost from benefit yields the net benefit of the product. Different products can then be ranked by their net benefit, and IOOS investments structured to produce first those products with the greatest net benefit.

Because of the time value of money, benefits are worth more if they are received sooner rather than later. For example, it is useful to distinguish benefits that derive from routine operational decisions in the short run (whether route the ship north instead of south), benefits that are realized in the longer term from improved investment decisions (how to design a breakwater), and benefits that accrue over very long periods of time (general economic growth due to better scientific and technical knowledge).

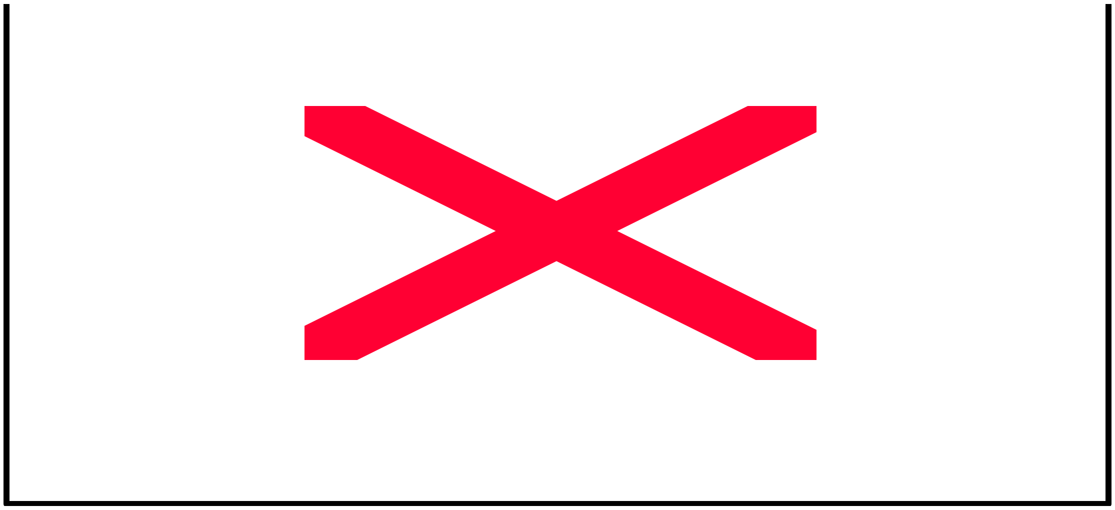
Some benefits are easier to estimate than others. In particular, the long term benefits from a general increase in scientific and technical knowledge are substantial and well understood, but (by definition) almost impossible to predict at the level of specific investments such as components of IOOS. The economic case for IOOS will focus on those products for which we are able to quantify benefits clearly, but the system's contribution to science and technology benefits to overall economic growth must be noted.

The overall cost of IOOS is an incremental accumulation of the costs of its products, but it is far less than the sum of the costs of individual products. This is an important efficiency that results from the integrated nature of the system. Individual observed variables will feed multiple products at little additional cost, and individual sensors will share platforms at little additional cost. It will help make the case for IOOS to show these efficiencies explicitly by estimating the full cost of individual products and then illustrating the savings possible by an integrated multi-product system.

We show below a simple example of how economic information can inform the IOOS system design process. We have taken a sample of 12 IOOS "products" or "subgoals" defined at the March 2002 Ocean.US IOOS workshop and qualitatively rated their incremental cost and benefit (see table below). Incremental cost is rated according to whether significant new observations and/or significant new modeling/processing effort is needed to provide the product. Benefits are rated according to the frequency of the event (number of people affected, for example) and the magnitude of the economic effect in each event. **Note that this example is for illustrative purposes only; no real significance should be attached to this simple assessment of benefits and costs, or to the resulting ranking.** At the very least, a preliminary quantitative estimate of costs and benefits should be developed before such a ranking is given serious weight in system design decisions.

	incremental cost		*benefit*		*timing of benefit*	
	more obs.	*more models*	*frequency of effects*	*unit magnitude*	*short term*	*long term*
SST variability			high	low	X	
ENSO prediction		X	high	high	X	X
sea level		X	high	high		X
HAB prediction	X	X	high	low	X	
anthropogenic contaminants	X	X	low	high		X
safe & efficient marine ops	X	X	high	high	X	X
SAR and spill response	X		low	high	X	
air & waterborne contaminant distribution and dispersion	X	X	low	high	X	
risk measures for swimming	X		high	low	X	
risk measures for seafood consumption	X		low	low	X	
fisheries stock assessments	X	X	high	low	X	X
natural hazard prediction (storms, etc.)	X	X	high	low	X	X

From these ratings, products can be sorted into a benefit/cost framework as shown in the following table. Ideally, the benefit and cost dimensions should be in (order of magnitude) numerical dollar terms. In this illustration, we define cost as "low" if a product requires neither significant new data nor new modeling, "medium" if it requires one but not the other, and "high" if it requires both. Benefit is defined as "high" if both frequency and unit magnitude are high, "medium" if only one is high, and "low" if neither is high. For simplicity, we ignore the timing of benefits at this stage.



The (red) number in the top left corner of each field represents a numerical approximation of net benefit (benefit minus cost) of products in this field. Ranking the products by these values leads to the following rough ordering (note that the order of products within each net benefit level is arbitrary):

6	SST variability ENSO prediction sea level
3	SAR & spill response risk measures for swimming safe & efficient marine operations
2	risk measures for seafood HAB prediction anthropogenic contaminants air/waterborne contaminant dispersion fisheries stock assessments hazard prediction

All of these products are worthwhile in the sense that all are likely to produce positive net benefits. If resources are limited and it is not possible to invest in producing all of them at once, this ranking can provide guidance on how to prioritize the investments. Some general guiding principles for IOOS investment planning are:

- Invest first in products that provide the highest net economic benefit, and then work toward products with lower (but positive) net benefit.
- Net benefits are likely to be highest when
    - a product leads to multiple sources of benefits (multiple uses), and/or
    - benefits accrue sooner rather than later.
- Use economic guidance in conjunction with assessments of technical impact/feasibility and political priorities to make the ultimate system design decisions.

To develop useful economic characterizations of IOOS products and ultimately conduct a more complete assessment of the economics of IOOS, it will be necessary to develop:

- data parameters and cost estimates for IOOS itself, and for value-added products to be derived from IOOS, including the means of distributing these products to users, and how the IOOS data and products differ from what is presently available
- a comprehensive list of industrial, recreational, and public administration activities that use products derived (in part) from ocean observation
- information about how these activities use ocean observation products (at present and, hypothetically, under IOOS) to make economic decisions
- information about how these decisions affect the (economic) outcome of their operations

Appendix: Recent Work on Benefits from Ocean Observations

Two areas in which the benefits of ocean observation have been shown to be significant are seasonal forecasts for agriculture and hydroelectric generation, and the use of ocean data in coastal management. Seasonal forecasts are one area where good estimates of the value of information exist, while coastal management problems have a tangible impact on the daily lives of millions of Americans who either live near the coast or visit the coast for recreational activities.

In agriculture, many decisions could be improved with a reliable seasonal weather forecast. One recent study found that by incorporating El Niño Southern Oscillation (ENSO) forecasts into planting decisions, farmers in the United States could increase agricultural output and produce benefits to the US economy of $275- 300 million per year. Another study estimated that the value to society of ENSO forecasts on corn storage decisions in certain years may be as high as $200 million—or one to two percent of the value of U.S. agricultural production. A third study on the costs and benefits of ENSO forecasts concluded that for agricultural benefits alone, the real internal rate of return for federal investments in ocean observation for ENSO prediction is between 13 and 26 percent.

While precipitation and temperature depend on the ENSO phase, they also depend on two other less-understood phenomena—the North Atlantic Oscillation, and the Pacific Decadal Oscillation. IOOS would help improve understanding of these two phenomena; if this led to better predictive capabilities, substantial improvements in seasonal forecasts would follow. This is an instance of direct evidence (in contrast to inferred evidence) that the incremental benefits of IOOS would be substantial, possibly of the same order of magnitude as those of the ENSO forecasts.

Because hydroelectric power generation is significantly affected by seasonal precipitation that differs across ENSO phases, an ENSO forecast should have significant value in managing water use for electricity production. For example, in the largest Tennessee Valley Authority reservoirs, winter stream flows in El Niño years can be as much as 30 percent above normal, allowing efficiency gains by switching from thermal to hydro power. Moreover, the benefits of seasonal forecasts for hydroelectric production, like those for agriculture, will increase if the North Atlantic Oscillation and the Pacific Decadal Oscillation can be forecast reliably.

There are a number of other areas where economic benefits from IOOS data may be significant, both from high seas and coastal ocean observations.

Public Health. Protective management of the U.S. coastal zones requires accurate information about contaminant flows in order to develop policy regarding wastewater treatment and disposal, trash disposal, airborne pollution control, beach closures, and public health restrictions on seafood consumption. For example, a new outfall pipe for treated sewage from the metropolitan Boston area is designed to shift waste inputs from Boston Harbor to Massachusetts Bay. However, the prospect of nutrient loading in the

Bay has raised concerns about possible effects on marine life and environmental conditions along the heavily used beaches of Cape Cod Bay. To address these concerns, extensive ocean monitoring is necessary to characterize marine environmental conditions in Massachusetts Bay and Cape Cod Bay prior to and after the utilization of the new outfall. IOOS would provide this kind of monitoring capability and help to predict or assess the consequences of alternative waste disposal decisions.

Coastal Management also includes the protection of beaches and public safety in beach use. Millions of Americans use coastal beaches throughout the year as a major source of recreation, and thousands of jobs in almost every coastal state depend on access to safe, clean beaches. Threats to these beaches are directly connected to the movement of ocean waters. In California and much of the east, combined sewer overflows can temporarily close beaches when high levels of untreated sewage are pumped into the sea following storms.

Oil spills are another threat that can damage beaches for months or years. In each of these cases, a thorough understanding of near shore ocean circulation, which is influenced by larger ocean patterns, is essential to knowing when and where the pollutants will go. In the case of oil spills, deployment of clean up equipment and strategies depends heavily on oceanographic models that in turn rely on the kind of ocean circulation data that does not exist but that IOOS may provide. While ocean data cannot eliminate beach closures or prevent oil spills, reliable data, analysis and interpretation can help reduce unnecessary precautionary beach closures, reduce the duration of closures, and minimize the potential damages from oil spills. Though direct estimates of the value of ocean data are not available, there is good reason to believe that this value is significant. For example, preliminary estimates of possible benefits from improved ocean observation in the Gulf of Maine are on the order of $30 million per year.

Other sources of economic benefits include the prevention of damage and deaths from storms, the ensuring of safety in design of offshore oil platforms, the facilitating of Naval operations, and the monitoring and understanding the processes of global climate change. Improved understanding of ocean processes may also lead to improved management of fishery resources, increasing long term potential output. Important values are at stake in most of these activities.

The contribution to the U.S. economy of industries and other activities that have been identified as likely beneficiaries of IOOS products is on the order of one trillion dollars.

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